

1 **IV. Remarks**

2  
3 The Office of Publications has given Notice of Drawing Inconsistency with  
4 Specification. At page 5 of the application in the Brief Description of the Drawings, there  
5 was not reference to Fig. 6. The reference to Fig. 6 has been added commencing at page  
6 5/line 19.

7  
8 With this fax is a Markup of the original application showing where the reference  
9 to Fig. 6 is added at page 5/line 19.

10  
11 With this fax is a Clean Copy of the application with the addition of the reference  
12 to Fig. 6 at page 5/line 19.

13 **SUMMARY OF THE AMENDMENT AND RESPONSE**

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15 Your applicant has made a good faith effort to respond to the Notice from the Office of  
16 Publication of January 31, 2007. Your applicant has addressed the inconsistency raised  
17 by the Office of Publications. Your applicant respectfully requests the Office of  
18 Publications to accept the correction and to advance this application to Publication.  
19

20  
21 Respectfully submitted,

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26 *Resubmitted March 1, 2007*

27 Certificate of facsimile filing  
28 on February 21, 2007 by Floyd E. Ivey,  
Serial No. 10/669,666 to 703,103,2065

Application No. 10/669,666

Floyd E. Ivey, USPTO 35552,

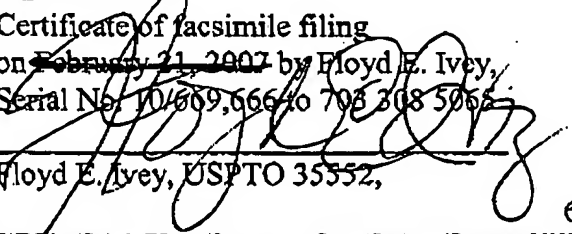
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27 Certificate of facsimile filing  
28 on ~~February 21, 2007~~ by Floyd E. Ivey,  
Serial No. 10/669,666 to 703 308 5065

Application No. 10/669,666

  
Floyd E. Ivey, USPTO 35552,  
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**MARKUP CHANGE AT PAGE 5**

METHOD OF PRODUCING CHARCOAL, CONDITIONED FUEL GAS AND  
POTASSIUM FROM BIOMASS

CONTINUATION - IN - PART

MARKUP  
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p 5

*This is a Continuation - in - Part application pending from Patent Application 10/254950 to Fred P. Beierle and entitled METHOD OF PRODUCING CHARCOAL FROM BIOMASS. New matter added at the filing of this Continuation-In-Part application is shown in italics and includes materials inserted at the Field of the Invention, Brief Description of the Drawings, Detailed Description and Claims. Addressed principally are factors relating to the production and processing of fuel gas produced from the charcoal production process of the parent, for use in combustion engines. Disclosed here is a process of preparing fuel gas from the charcoal production apparatus and process, described in the parent and as seen herein, for use in diesel engines or any combustion engine.*

Field of the Invention

*This invention relates to the production of charcoal and fuel gas for combustion engines. More particularly, this invention relates to the maximization of charcoal production with the production of fuel gas as a secondary consideration. Fuel gas is conditioned for use in combustion engines. The parent application is abandoned with the filing of this Continuation-in-Part application.*

Background of the Invention

*This invention relates generally to the art of producing charcoal, and secondarily fuel gas, from organic material, and more particularly concerns an apparatus and method in such art which is self-sustaining in operation.*

*The use, per se, of a pyrolysis process to convert organic material, such as wood chips, to charcoal and fuel gas is well known, and a wide variety of devices*

2 devices, including those generally referred to as gasifiers, is that a substantial  
3 produced charcoal is substantially consumed. A recognized by-product of the  
4 pyrolysis process is tar, which affects both the operation of a gasifier and the end use  
5 apparatus of the produced fuel gas, such as an internal combustion engine or other  
6 burner. The production of tar is discussed in U.S. Pat. No. 4,268,275 and U.S. Pat.  
7 No. 4,421,524 both to Chittick and U.S. Pat. No. 4,530,702 to Feters et al. The  
8 solution regarding tar, disclosed in these patents, included a reaction chamber having  
9 a pyrolysis zone followed by a reaction zone comprising a bed of charcoal heated to a  
10 high temperature. The high temperature of the charcoal and the catalytic effect of the  
11 ash residue on the surface of the hot charcoal break down the tars from the pyrolysis  
12 zone into carbon monoxide and hydrogen. The heat for the pyrolysis zone and the  
13 reaction zone was provided externally. The issue of minimizing the consumption of  
14 charcoal is not addressed. U.S. Pat. No. 4,530,702 to Feters et al additionally  
15 disclose the introduction of steam for increased fuel gas production. The introduction  
16 of steam is counterproductive vis-a-vis the production of charcoal increasing the  
17 production of carbon fines and production of ash, both having little or no value.

18 Also noted herein are U.S. Patents to Brioni et al, 5,725,738; to Koslow,  
19 5,946,342 and 6,061,384; and Nagle et al, 6,051,096 and 6,124,028.

20 The patents referred to herein are provided herewith in an Information  
21 Disclosure Statement in accordance with 37 CFR 1.97.

22

23

#### Summary of the Invention

24

25 The present invention includes a process for producing charcoal, and  
26 secondarily fuel gas, from organic material, in which a charge of charcoal is initially  
27 present in a pyrolysis reaction chamber, thus forming a charcoal bed therein, the  
28 process being self-sustaining so that it does not require the addition of external heat  
29 following initiation of the process, wherein the process comprises the steps of:  
30 igniting a portion of the charcoal bed within the pyrolysis reaction chamber, the  
ignition being substantially uniform over the cross-sectional area of the charcoal bed;  
moving air through the charcoal bed so that the portion of ignited charcoal becomes

2 material, typically in the form of pellets or chips or the like, to the reaction chamber  
3 on top of the charcoal bed; forming a head of raw unreacted fuel; and establishing  
4 and maintaining a zone in the pyrolysis zone in which the combustion is  
5 homogeneous, the zone of homogeneous combustion extending over the entire  
6 cross-sectional area of the pyrolysis zone. In addition, the steps of igniting, removing  
7 charcoal and adding biomass, and with and without the steps of establishing and  
8 maintaining, the step of directing additional air into the charcoal from beneath the  
9 charcoal bed is added, providing a capability to maximize the production of charcoal  
10 and minimize the consumption of charcoal within the apparatus. Disclosed herein is  
11 the production of charcoal in a charcoal production bed in a single reaction chamber  
12 the production bed comprising in sequence (a) an upper layer of biomass input  
13 material, (b) an intermediate pyrolysis zone layer in which the input material is  
14 reduced to devolatilized char and pyrolysis volatiles comprising hydrogen, carbon  
15 monoxide, methane, nitrogen, water vapor and tars, the intermediate layer being at a  
16 temperature within the range of 800 degrees C. to 1000 degrees C., and (c) a lower  
17 layer comprising substantially only hot charcoal. The gases produced are generally as  
18 follows as a percentage of total gas produced: Hydrogen 17-18%; Carbon Monoxide  
19 38%; Methane 2%; with the remainder primarily Nitrogen with some trace gases also present.

20       Secondarily, the present invention includes an apparatus for converting a  
21 biomass input to an output gas which is suitable for use as a fuel gas, wherein the  
22 apparatus includes a reaction chamber which is open at its lower end, in which, in  
23 operation, a bed of charcoal is present in which in turn is located a pyrolysis reaction  
24 zone. The pyrolysis reaction converts the biomass input into fuel gas volatiles and  
25 charcoal. Air is drawn down through the reaction chamber from above the pyrolysis  
26 zone and fuel gas exits from the apparatus. In contrast to prior art, there is no  
27 provision for additional air to be directed into the charcoal bed from below the bed.  
28 Such lessens the production of charcoal and operates to the detriment of the purposes  
29 of this invention.

30       Control and instrumentation includes a control motor drive of an auger means  
for removal of charcoal having instrument means to detect quantities of charcoal to

2 lines which includes a pressure sampling means for sampling the gas pressure in the  
3 output line; control means including control valve means positioned in a return line  
4 which, when open, permits recirculation of a portion of the gas in the output line; and  
5 control means responsive to the pressure in the output line, as sampled by the  
6 sampling means, e.g., pressure transducers having an input to a control valve means,  
7 to open the normally closed valve means when the pressure rises above a  
8 predetermined valve. Control and instrumentation means include but are not limited  
9 to temperature, pressure, level or height and other control and measurement means  
10 which may be accomplished, as recognized by those of ordinary skills in the control  
11 and measurement arts, with thermocouple and other temperature measurement  
12 instruments, pressure transducer and other pressure measurement instruments, stress  
13 gages and other stress measurement instruments, light detectors and limit switches  
14 and other level measurement instruments having controller inputs to controllers for  
15 valve, process and other control functions as are commonly recognized by those of  
16 the instrumentation and control arts.

17 *Combustible fuel gas is a by-product of the charcoal production described in*  
18 *the parent application. Fuel gas is discharged to a heat exchanger, a demister, a fuel*  
19 *conditioner and to either storage or combustion in an engine means. A by product of*  
20 *the heat exchanging process is water containing potassium usable as an agricultural*  
21 *fertilizer.*

22

### 23 Brief Description of the Drawings

24 The foregoing and other features and advantages of the present invention will  
25 become more readily appreciated as the same become better understood by reference  
26 to the following detailed description of the preferred embodiment of the invention  
27 when taken in conjunction with the accompanying drawings, wherein:

28 FIG. 1 is a cross-sectional diagram of the invention showing a charcoal  
29 production bed (10) in a single reaction chamber (30) where the production bed (10)  
30 comprises in sequence (a) an upper layer (13) of biomass input material, (b) an  
intermediate layer (14) pyrolysis zone layer in which the input material is reduced to

5 reduce any tars from the pyrolysis zone layer to carbon monoxide and hydrogen; the  
6 charcoal production bed having an outlet means (43) for fuel gas. The reaction  
7 chamber (30) receives air input (50) at the upper layer (13). Seen is removal means  
8 (45), seen here as an auger, for removal of charcoal.

9 FIG. 2 is a flow diagram of the invention of FIG. 1.

10 FIG. 3 is a flow diagram showing the fuel gas output (44) from the invention  
11 of FIG. 1. Illustrated is the introduction of hot fuel gas (44) into a heat exchanger  
12 means (60) and into a water or coolant reservoir (65) with the exhaust of the cooled  
13 fuel gas seen as output from water or coolant reservoir (65) directed to a demister  
14 means (80) followed by directing the demister output (82) to a fuel conditioner means  
15 (100) where said fuel conditioner output (130) is stored or combusted in an engine  
16 means (140).

17 FIG. 4 and FIG. 5 illustrates details 4 and 5 from FIG. 3 showing an aspect  
18 of the fuel conditioner means (100)

#### 19 Detailed Description

20  
21 FIG. 1 shows the preferred embodiment of the present invention, which in  
22 operation is self-sustaining, in that it requires no external heat source to maintain  
23 operation. The reaction chamber (30) may be composed of heat and corrosion  
24 resistant materials including, for example, fiber-ceramic insulating material, lined  
25 interiorly with unreactive inconel or stainless steel metal, either of which resist attack  
26 from oxygen. In the preferred embodiment the reaction chamber will have a circular  
27 cross-section but may be formed with a variety of cross-sections. Those of ordinary  
28 skills in the heat and corrosion arts will appreciate other materials suitable for the  
29 reaction chamber (30).

30 In the preferred embodiment diameter of the reaction chamber (30) is  
substantially uniform along its length, except for the uppermost portion or upper layer

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Fig. 6 illustrates a detail from Fig. 3 showing the funnel means (200) having a  
slope,  $\theta$  (210) at the funnel side (220), relative to a vertical, and of the charcoal  
discharge funnel means (230) having a slope,  $\theta$  (240) of charcoal discharge funnel  
slope (240) relative to a vertical where the slope will be greater than approximately  
45 degrees and are preferred at approximately 60 degrees and showing that both the  
funnel means (200) and the charcoal discharge funnel means (230) are primarily  
inverted conical in structure.



2 water vapor and tars, the intermediate layer being at a temperature within the range of  
3 800 degrees C. to 1000 degrees C., and (c) a lower layer (15) comprising substantially  
4 only hot charcoal, the hot charcoal being at a temperature which is sufficiently high to  
5 reduce any tars from the pyrolysis zone layer to carbon monoxide and hydrogen; the  
6 charcoal production bed having an outlet means (43) for fuel gas. The reaction  
7 chamber (30) receives air input (50) at the upper layer (13). Seen is removal means  
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13 fuel gas seen as output from water or coolant reservoir (65) directed to a demister  
14 means (80) followed by directing the demister output (82) to a fuel conditioner means  
15 (100) where said fuel conditioner output (130) is stored or combusted in an engine  
16 means (140).

17 FIG. 4 and FIG. 5 illustrates details 4 and 5 from FIG. 3 showing an aspect  
18 of the fuel conditioner means (100)

19

#### 20 Detailed Description

21 FIG. 1 shows the preferred embodiment of the present invention, which in  
22 operation is self-sustaining, in that it requires no external heat source to maintain  
23 operation. The reaction chamber (30) may be composed of heat and corrosion  
24 resistant materials including, for example, fiber-ceramic insulating material, lined  
25 interiorly with unreactive inconel or stainless steel metal, either of which resist attack  
26 from oxygen. In the preferred embodiment the reaction chamber will have a circular  
27 cross-section but may be formed with a variety of cross-sections. Those of ordinary  
28 skills in the heat and corrosion arts will appreciate other materials suitable for the  
29 reaction chamber (30).

30 In the preferred embodiment diameter of the reaction chamber (30) is  
substantially uniform along its length, except for the uppermost portion or upper layer

2 be comprised, for example, of fuel pellets, vegetable matter and other organic matter  
3 as will be appreciated by those of ordinary skill in the art. Biomass (20), in the  
4 preferred embodiment is delivered by delivery means (16) into the reaction chamber  
5 (30) by an motor controlled auger (16). In the preferred embodiment a light detection  
6 means, provided in the preferred embodiment as a electric eye (22), is mounted by  
7 mounting means at a top (31) of the reaction chamber (30). The electric eye (22) set  
8 provides a switch function electrically communicating with a motor drive for the  
9 motor controlled auger (16) causing power to the motor controlled auger (16) when  
10 the electric eye (22) detects the absence of biomass. Delivery means (16) may  
11 include hoppers, conveyors, augers and other such feed or delivery devices. The  
12 preferred embodiment for delivery means (16) is by motor controlled auger (16).

13 FIG. 1 is a cross-sectional diagram of the invention showing a charcoal  
14 production bed (10) in a single reaction chamber (30) where the production bed (10)  
15 comprises in sequence (a) an upper layer (13) of biomass input material, (b) an  
16 intermediate pyrolysis zone layer (14) in which the input material is reduced to  
17 devolatilized char and pyrolysis volatiles comprising hydrogen, carbon monoxide,  
18 water vapor and tars, the intermediate layer being at a temperature within the range of  
19 800 degrees C. to 1000 degrees C., and (c) a lower layer (15) comprising substantially  
20 only hot charcoal, the hot charcoal being at a temperature which is sufficiently high to  
21 reduce any tars from the pyrolysis zone layer to carbon monoxide and hydrogen; the  
22 charcoal production bed (10) having an outlet means (43) for fuel gas. Seen is  
23 charcoal removal system (40) comprised of removal means (45), shown for example  
24 as an auger but which may be provided by a valve controlled chute, screw drive and  
25 other lift or moving devices; also seen as a part of a removal system (40) is the  
26 conveyance or routing means (34) and charcoal storage means (36).

27 Control of removal means (45) is effected by temperature sensing means, e.g.,  
28 thermocouples or other recognized temperature sensing devices, positioned in the  
29 reactor chamber (30) where the temperature sensing means has an output received by  
30 a controller for a delivery means (16). In the preferred embodiment temperature  
sensing means is provided by at least one thermocouple (24) at the upper layer (13)

2 the preferred embodiment by three thermocouples (24) positioned respectively at the  
3 upper layer (13), intermediate layer (14) and at the delivery means (16). In the  
4 preferred embodiment a thermocouple positioned in the reactor chamber (30) at the  
5 intermediate layer (14) will detect a temperature change indicating the rising of the  
6 pyrolysis zone and will provide switch means for the control of a motor controlled  
7 auger removal means (45) to move the intermediate layer (14) down in the reaction  
8 chamber (30); a thermocouple at the top (31) of the reaction chamber (30) will  
9 provide high temperature information for safety shutdown of a fuel gas pump (42)  
10 thereby terminating air flow and the operation of the system; a third thermocouple at  
11 the delivery means (16) provides additional high temperature sensing and safety  
12 control for pump (42) control. Circuit interconnections from one or a plurality of  
13 thermocouples to controllers are not shown and are not claimed herein as inventive  
14 elements of this disclosure.

15 It is noted that the charcoal moved from the lower layer (15) will be may be in  
16 the range of 600-700 degrees F. Hence this removed charcoal must be contained in  
17 an environment which is essentially oxygen free, lest it combusts, until it has cooled.  
18 Conveyance or routing means (34) may be auger via piping, conveyor or other such  
19 device. Eventual charcoal storage, not shown, may be, for example, bins, trucks, and  
20 other such containers suitable for storage or transport to a processing facility.

21 Prior to initiation of operation, the reaction chamber (30) lower layer (15) is  
22 filled with devolatilized charcoal. The devolatilized charcoal is substantially uniform  
23 in size and configuration, although the particular size of the charcoal will depend to  
24 an extent on the size of the reaction chamber. The lower layer (15) of the charcoal  
25 production bed (10) is then ignited, typically, but not necessarily, at or near the lower  
26 layer top (33) thereof by ignition means, e.g., a torch, electric start, or similar device.  
27 Following ignition of the lower layer top (33), biomass (20) is added forming the  
28 upper layer (13) and atmospheric air (50) is moved downwardly through the reaction  
29 chamber (30) and production bed (10) by means of a pump (42) which is typically  
30 located in fuel gas outlet means (43) line so that air (50) is drawn into and through the  
reaction chamber (30) from the atmosphere above the reaction chamber (30) in that

2 layer (14) forms the pyrolysis zone as air (50) is drawn through the production bed  
3 (10). Alternatively, a source of pressurized air may be used at the top (31) of the  
4 reaction chamber (30) to force air (50) through the reaction chamber (30) and out the  
5 outlet means (43).

6 It is important for tar-free operation of the invention that the combustion  
7 reaction in the pyrolysis zone be substantially homogeneous over the cross-sectional  
8 area of the reaction chamber (30). This means that the temperature profile across the  
9 pyrolysis zone (14), over the cross-section of the reaction chamber (30), should be  
10 substantially uniform, so that there are no hot spots or channels in the pyrolysis zone  
11 (14). Maintaining a homogeneous intermediate layer (pyrolysis zone) (14) results in  
12 the intermediate layer (14) being relatively thin, no matter what the size of the  
13 reaction chamber (30). Any tars which are produced in such an intermediate layer  
14 (14) are rather light in weight and are completely broken down by the hot lower layer  
15 (15) charcoal bed below the intermediate layer (14).

16 The pyrolysis reaction is homogeneous in the preferred embodiment shown  
17 largely because the airflow through the reaction chamber (30) is substantially uniform  
18 over the cross-sectional area of the chamber (30), particularly over the pyrolysis zone  
19 (14). Thus, a uniform pressure exists over the cross-sectional area of the chamber  
20 (30) in the embodiment shown. To insure that this occurs, the structure by which air  
21 (50) is provided to the reaction chamber (30) should not be such as to channel air into  
22 the reaction chamber (30), such as occurs with tuyeres, for instance. Air (50) must be  
23 permitted to disperse evenly over the top (31) of the biomass (20) raw fuel head upper  
24 layer (13) and to be drawn down uniformly through the head or upper layer (13).  
25 Further, the size of both the biomass (20) particles, and the charcoal in the lower  
26 layer (15) of the charcoal production bed (10) should be somewhat uniform in size.  
27 Excessive "input dust", i.e., more than 10%-25% or so, comprised, for example of  
28 fine biomass (20) particles, will likely have a detrimental affect on the operation of  
29 the invention. Uniform biomass (20) particle size helps to insure a uniformity of  
30 airflow through the chamber (30), at least over the cross-sectional area of the  
intermediate layer (14). This in turn assists in maintaining a uniform temperature

2 intermediate layer (14), which minimizes localized hot spots and/or channels in the  
3 intermediate layer (14), thus resulting in a homogeneous combustion of the biomass  
4 (20) throughout the intermediate layer (14).

5 It should be understood that additional techniques, perhaps involving screens  
6 or other gas dispensing devices, may be used to insure uniformity of airflow through  
7 the chamber and a uniform temperature profile. Further, although atmospheric air has  
8 been used as an example of the gas which is moved through the chamber, it should be  
9 understood that other gases, including oxygen-enriched atmospheric air, or pure  
10 oxygen, could be used.

11 The establishment of a intermediate layer (14) with homogeneous combustion  
12 may be assisted by a biomass leveling means (52) provided for example by a cone  
13 (52) fixed by cone affixing means at reactor chamber top (31). Prior art demonstrated  
14 stirring of the lower layer (15) of the charcoal production bed (10) following ignition.  
15 It is seen that stirring degraded the charcoal into fines and is counterproductive to the  
16 production of charcoal of usable particle size. As mentioned above, the resulting  
17 intermediate layer (14) is relatively thin, regardless of the size of the reaction  
18 chamber (30), and has a temperature of approximately 900.degree. C. Typically, the  
19 time necessary for uniform ignition of the lower layer (15) of the charcoal production  
20 bed (10), and for establishment of the intermediate layer (14), is very short, i.e. a few  
21 minutes. After the intermediate layer (14) has been established, biomass (20) is fed  
22 into the reaction chamber (30), into the area of the intermediate layer (14) on top of  
23 the lower layer (15), so that three zones are established in the chamber; specifically,  
24 the thin, hot intermediate layer (14) between the head of cool, unreacted biomass (20)  
25 at the upper layer (13) and the lower layer (15).

26 The biomass (20) particles, once they reach the intermediate layer (14), are  
27 reacted by the high temperature to produce charcoal and essentially tar-free fuel gas.  
28 The temperature of the exiting gas is typically 50.degree. C. to 100.degree. C. below  
29 the temperature of the intermediate layer (14), depending on radiation losses. The fuel  
30 gas is essentially tar-free because there are no localized inhomogeneities in the  
combustion in the intermediate layer (14), such as hot or cool channels, through

2 into heavy tars. With homogeneous combustion in the intermediate layer (14), any  
3 tars emanating from the biomass (20) particles are light, and the tar molecules are  
4 small. These light tars, in the absence of channels or a long intermediate layer (14)  
5 are then reacted by the catalytic action of the hot charcoal bed to form carbon  
6 monoxide and hydrogen. Thus, the gas output of applicant's invention is reliably  
7 tar-free.

8 As the biomass (20) particles move through the intermediate layer (14),  
9 which is typically at a temperature of approximately 900.degree. C. but which can  
10 operate effectively over a temperature range of 750.degree. C. to 1000.degree. C.,  
11 fuel gas is produced and a devolatilized char is left behind. Thus, the boundary line  
12 between the intermediate layer (14) and the lower layer (15) is where the biomass  
13 (20) particles have been reduced to devolatilized char.

14 After a short period of operation, the temperature of the lower layer (15)  
15 becomes quite hot, typically in the range of 800.degree. C. to 950. degree. C. Any tars  
16 which do escape from the intermediate layer (14), which are light, as explained  
17 above, are broken down by passage through the hot lower layer (15) of the charcoal  
18 production bed (10) with resulting fuel gas exiting through outlet means (43) line.  
19 However, inhomogeneities in the intermediate layer (14) result in the volatilized  
20 gases polymerizing into large, heavy molecules forming clinkers. Additionally,  
21 where biomass (20) of high silica content is used, the operating temperature of the  
22 intermediate layer (14) should be controlled to the lower area of the temperature  
23 range at about 800 degrees C. Clinkers are particularly susceptible to formation  
24 where the biomass (20) is largely comprised of silica including grasses, straw and  
25 hay. Where such biomass (20) is used temperature control is critical. Temperature  
26 control in the preferred embodiment is by manual control of the pump (42). Those of  
27 ordinary skill will recognize that temperature sensing and valve control is readily  
28 available in the industry. Ash and other fines which are created by the operation of  
29 the system of the present invention are carried out with the gas and removed by filter  
30 (41), which is in the preferred embodiment is a bubbler tank comprised of a tank of  
water through which the fuel gas is "bubbled". The filter (41) may, for instance, be a

2 ordinary skill in filtering arts..

3 Because the intermediate layer (14) is relatively thin, and substantially  
4 homogeneous in reaction, ignition and initiation of operation of the gasifier may be  
5 accomplished rapidly, typically much faster than with conventional gasifiers. The unit  
6 is also very responsive to changes in demand. The volume of fuel gas (44) output  
7 from the gasifier is proportional to the quantity of air (50) flow through the unit, as a  
8 change in the air-flow causes a corresponding change in the rate of biomass (20) fuel  
9 consumed, and hence, the amount of gas (44) produced.

10 Another advantage of the homogeneous intermediate layer (14) described  
11 above is that the unit is stable in operation, i.e. it produces a usable, tar-free gas (44)  
12 output over a relatively wide range of input and output demands. Various kinds of  
13 material may be used as biomass (20) input, including wood, straw, and other organic  
14 materials, as long as the above size and configurational requirements are observed.  
15 The unit is to an extent self-correcting in operation. If an inhomogeneity occurs,  
16 additional heat will typically be produced in the vicinity of that inhomogeneity. The  
17 additional heat then disperses over the entire intermediate layer (14), tending to  
18 disperse the inhomogeneity.

19 The homogeneity of the reaction of the intermediate layer (14), including the  
20 substantially uniform temperature profile, contributed to by the substantial uniformity  
21 in size and configuration of the biomass (20) and the uniformity in air (50) flow over  
22 the cross-sectional area of the reaction chamber (30), substantially eliminates hot spot  
23 channels which characterize the operation of previous gasifiers. Any tars generated  
24 in the intermediate layer (14) of the gasifier disclosed herein, are lightweight, small  
25 molecules, as described above, and are broken down in a catalytic reaction by contact  
26 with the devolatilized charcoal in the hot charcoal bed.

27 Even with a homogeneous radiation condition over the cross-section of the  
28 intermediate layer, however, the gasifier can be over-driven to the extent that  
29 channels are created in the pyrolysis zone and the charcoal production bed (10),  
30 resulting in tars and clinkering. Thus, the velocity of the air (50) moving through the  
unit is important to proper operation of the gasifier. In some instances, the gasifier is

low. As the velocity of the air (50) increases, size uniformity of the biomass (20) input becomes more significant. The inventors have found that a velocity of 0.27 cubic ft. of air per minute per sq. inch of cross-sectional area provides a good output without overdriving the unit. A reasonable range of air (50) velocity including the above value will provide satisfactory results.

With certain kinds of biomass (20) input, the relative dimensions of the three zones will remain substantially stable within the chamber (30), with the consumption of charcoal occurring at approximately the same rate as char is produced from the fuel pellets in the pyrolysis zone. Such a circumstance is undesirable relative to the goal of charcoal production. With most types of biomass (20) fuel inputs, such as dry wood pellets, more charcoal will be produced by the pyrolysis reaction than is consumed in the charcoal bed. In such a case, the level of the charcoal bed gradually rises, raising the pyrolysis zone. At some point then, charcoal must be removed from the chamber if proper operation is to continue. The excess charcoal can be removed in a number of ways, either mechanically, or by changing fuel to one with a high moisture content so that more charcoal is consumed than is produced by pyrolysis, or by the addition of water or steam to the reaction chamber.

*Figure 3 illustrates the process of conditioning fuel gas (44) for consumption in a combustion engine or for storage. The Fuel Gas (44) output is approximately 1000 degrees F. Disclosed here is the conditioning of the fuel gas (44) for use in a combustion engine. Hot fuel gas (44) is directed into a heat exchanger means (60) having water or coolant supply inlet (67) and water or coolant discharge (69). Heat exchanger means (60), in the preferred embodiment is the direction of the hot fuel gas (44) into a heat exchanger tank (60) containing water (65) wherein the hot fuel gas (44) bubbles through the water (65) to be exhausted from the heat exchanger tank (60) at a heat exchanger tank exhaust (71). Heat exchanger means (60) may be supplemented by a supplemental heat exchanger means (62) comprising structure from generally recognized heat exchanger means including but not limited to a tube heat exchanger wherein the hot fuel gas (44) is received into a supplemental heat*



2 in fluid contact with the heat exchanger tank (60) contents, including as indicated in  
3 this application, water (65) with the cooled fuel gas (44) then exhausted at a heat  
4 exchanger tank exhaust (71). Those of ordinary skills in the heat exchanger arts will  
5 recognize other heat exchanger structures equivalent to a tube heat exchanger.

6 The output from the heat exchanger tank exhaust (71) is a combination of  
7 water vapor and fuel gas (44) and is directed then into a demister means (80) at a  
8 demister input (81). The demister means (80) accumulates some portion of the water  
9 vapor by condensation forming condensate (83). In the preferred embodiment the  
10 demister means (80) is comprised of the input via at least one tube (81) and, as is  
11 represented in Fig. 3, a flow diagram, a plurality of tubes 1...n (81) or other  
12 equivalent means with the condensate (83) accumulated in the demister means (80)  
13 and with the condensate (83) periodically drained from the demister means (80) by a  
14 condensate drain means (84) comprised generally of a valve and piping means  
15 discharging into a reservoir or other place for discharge of the condensate (83). The  
16 fuel conditioner means input (110), is then directed through bubble forming means  
17 (115) into and through a fuel conditioner means (100) containing fuel means (120).  
18 Bubble forming means (115) is provided, in the preferred embodiment, by directing  
19 the fuel conditioner input means (110) via pipe or tube means (110) to and through a  
20 grid (116) formed of fine wire mesh or a plate with at least one aperture (117) as is  
21 seen in Figures 4 and 5. Fuel means (120) includes but is not limited to diesel,  
22 peanut oil, vegetable oils and other combustible substances as will be recognized by  
23 those of ordinary skill in the arts as combustion engine fuels. The fuel conditioner  
24 output (130) will be a mixture of fuel gas (44) and fuel means (120) which is  
25 exhausted via pump means (140) exerting a vacuum at the fuel conditioner output  
26 (130). Fuel conditioner output (130) is directed to a storage or combustion at an  
27 engine means (160).

28 Valve means, not shown in Figure 3, controls the water or coolant supply  
29 inlet (67) and water or coolant discharge (69) and the condensate drain (84). Pipe  
30 or tube means (75) provides fluid communication from fuel gas (44) input to heat  
exchanger means (60), between heat exchanger means (60) and demister means (80);

2 conditioner means (100) and storage or engine means (160).

3       The fuel conditioner output (130), a mixture of fuel gas (44) and fuel means  
4 (120), will be, in the preferred embodiment, in the range of 5% to 20% diesel with the  
5 balance comprised of fuel gas (44). With a combination of approximately 3.8%  
6 diesel and 96.2% fuel gas (44), substantial pinging has been experienced. It has  
7 been noted that controlled delivery of diesel, to the cylinders of a diesel engine,  
8 lessens or stops pinging when each cylinder receives the same diesel concentration in  
9 the fuel gas (44) and fuel means (120). Operation of diesel engines is difficult when  
10 the diesel concentration in the conditioned fuel gas (44) is below 5% diesel. The  
11 preferred embodiment of the output of the fuel conditioner output (130) will be with  
12 diesel in the range of 5% to 10% and fuel gas (44) at 95% to 90%. The use of diesel  
13 and fuel gas (44), forming the conditioned fuel gas (130) requires lower compression.

14       The conditioned fuel gas (130), as fuel for diesel engine means (160),  
15 eliminates the need for fuel injectors due to the diesel content of the conditioned fuel  
16 gas (130). Testing demonstrates that the conditioned fuel gas (130) also functions  
17 with spark ignition combustion engine means (160). Use of the conditioned fuel gas  
18 (130) with diesel engine means (160) also eliminates the need for glow plugs for  
19 ignition when the ratio of diesel is increased in the conditioned fuel gas (130).  
20 Alternative operations may commence with the starting of the engine means (160)  
21 with traditional fuels with injection and glow plug means, with injection and glow  
22 plug mean deactivated when the conditioned fuel gas (130) is introduced. The  
23 conditioning with diesel, at the fuel conditioner means (100) also acts to remove tars  
24 which may be transferred with the fuel gas (44). The conditioned fuel gas (130) may  
25 be introduced directly into the engine intake manifold.

26       The water or coolant discharge (69) where the coolant is water, is found to  
27 have concentrations of chemicals supportive of increased growth of plants. It is  
28 understood that the chemicals introduced into the water or coolant discharge (69)  
29 includes potassium. Experimentation has demonstrated increased growth of plants  
30 when watered with the water or coolant discharge (69).

It is noted, by reference to Figure 6 as a detail from FIG. 1, in the process of

2 (12) may tend to drop in level relative to the upper layer (13) proximal a reaction  
3 chamber wall (32) and proximal the top (31). Introduction of biomass (20) into a  
4 funnel means (200), will direct biomass (20) toward the upper layer center (12)  
5 thereby reducing the tendency of dropping in level at the upper layer center (12). A  
6 similar obstructing event occurs at the discharge of charcoal from the lower layer  
7 (15) to the charcoal removal system (40). The charcoal from the lower layer (15)  
8 falls into the charcoal removal system (40) and tends, toward the walls of the  
9 charcoal removal system (42) to stack and not readily advance toward the removal  
10 means (45). The introduction of a charcoal discharge funnel means (230)  
11 intermediate the lower layer (15) and the removal means (45), directs the charcoal  
12 away from the walls (42) of the charcoal removal system (40) and toward the  
13 removal means (45). The slope,  $\theta$  (210, 240) of the funnel means (200) at the funnel  
14 side (220), relative to a vertical, and of the charcoal discharge funnel means (230) at  
15 the charcoal discharge funnel slope (240), in the preferred embodiment, will be  
16 greater than approximately 45 degrees and are preferred at approximately 60  
17 degrees. Both the funnel means and the charcoal discharge funnel means (230) are  
18 primarily inverted conical in structure. Other cross sections will be equivalent as  
19 will be appreciated by those of ordinary skill in the funnel arts.

20 The high temperature of collecting charcoal at the charcoal removal system  
21 (40) and charcoal collection means (41) provides heat to be captured by introduction  
22 of a charcoal heat exchanger means (260) provided, in the preferred embodiment by  
23 at least one tube (262) penetrating the charcoal collection means (41) arena via heat  
24 exchanger ports (264) at the charcoal removal system wall (42).

25

26 While a preferred embodiment of the present invention has been shown and  
27 described, it will be apparent to those skilled in the art that many changes and  
28 modifications may be made without departing from the invention in its broader  
29 aspects. The appended claims are therefore intended to cover all such changes and  
30 modifications as fall within the true spirit and scope of the invention.